

mella is a product of the periotic capsule, such as the stapes has been assumed to be?

Here, I think, there is considerable ground for hesitation. It appears to me that the stapes is not so much "cut out" of the cartilaginous periotic capsule as the result of the chondrification of a portion of that capsule which remains unchondrified longer than the rest. Moreover, the *Urodela* all possess a band of ligamentous fibres which extends from the stapes to that part of the suspensorium with which the hyoid is connected, and to the hyoid itself. It is conceivable, and certainly not improbable, that this stapedio-suspensorial ligament represents the dorsal extremity of the hyoidean arch. But the *columella auris*, in its early condition in the frog, so nearly resembles the stapedio-suspensorial ligament partially chondrified, that it is hard to suppose that one is not the homologue of the other; in which case the columella, and even the stapes itself, may, after all, represent the metamorphosed dorsal end of the hyoidean arch or the hyomandibular of a fish. And it must be admitted that the relations of the portio dura nerve to the hyomandibular in such a fish as the Ray, speak strongly in favour of this view.

ON MIRAGE*

II.

WE will now modify our imaginary distribution of density in such a way as to adapt it to a convex earth. To do this we have merely to bend our diagram to the earth's curvature.

The result is shown in Fig. 3 (Plate I.), where the dotted line represents a level line coincident with a stratum of equal density in the earth's atmosphere, and, like any other level line, partaking of the general curvature of the earth. It is of the same length as the dotted line in our first diagram, and ordinates (offsets), equal to those in Fig. 1, are laid off from it, in normal directions, at the same number of equidistant points. The curves thus obtained possess all the properties, as regards foci and images, which we have pointed out as belonging to those of Figs. 1 and 2; and we can now afford to dispense with the difficult physical postulate of a diminution of density downwards from the plane of reference. One of the rays in Fig. 3 is everywhere concave downwards, and therefore the air which it traverses increases in density downwards.

If we suppose the law which gave Figs. 1 and 2 (Plate I.) to hold only on one side of the plane of reference, while on the other side of this plane the density is uniform, we shall have conjugate foci for points in the plane of reference, but for no other points. The conjugate foci will themselves be in the plane of reference, and the distance from any point to its conjugate will be constant. Rays coming to the plane of reference from the side on which the density is uniform will be bent round so as to meet the plane of reference again at a constant distance in advance of the points at which they entered, and the angle of emergence will be equal to the angle of incidence. More generally, whenever there is a layer of air in which the density diminishes very rapidly from one side to the other, while the density elsewhere is comparatively constant, rays entering this variable stratum from the denser side will (if their inclinations to the stratum are not too great) bend round in it and emerge from it again on the same side, as in Figs. 4 and 5. In Fig. 4 the dotted line may be supposed to represent a plane, beneath which the density diminishes more rapidly down to the ground (which is represented by the shading). In Fig. 5 the shading represents a stratum in which the density diminishes rapidly in ascending, the diminution being most rapid at the middle of the stratum. In both cases, the

appearance presented to an eye at E will be nearly the same as if the rays had been reflected from a plane mirror behind and parallel to the stratum; I say *nearly* the same, because the position of the equivalent plane mirror will not be precisely the same for rays at different inclinations to the stratum. Objects will thus be seen inverted, without being necessarily either magnified or diminished. Fig. 4 is intended to illustrate the mirage of the desert, and Fig. 5 to illustrate the formation of inverted images in looming. In Fig. 4, tracing the three rays backwards from the observer's eye at E, the lowest of the three at the eye end is bent up just sufficiently to prevent it striking the ground, and then goes away to the sky, so that he will see the sky as if reflected from the ground. The second ray does not pass quite so near the ground, and it goes away to a lower part of the sky. The third ray follows a similar course, not descending quite so near the ground, and going off in a direction more nearly horizontal. We may suppose it to be terminated by a tree, hill, or other tall object, which will accordingly be seen reflected beyond the image of the sky.

Rays a little higher than this will escape the upward bending which has produced these effects, and which is due to the action of a comparatively thin stratum of air near the ground. The same objects which have been seen apparently reflected by the ground will thus be also seen erect in their true positions. The relation between the appearances of the true and the reflected objects is almost precisely the same as if there were a sheet of water occupying the place of the ground; and the flickering of the air as the hotter and colder currents ascend and descend will bear a close resemblance to waves ruffling the surface of the imaginary lake.

The earliest explanation of mirage, I believe, on record is that of Monge (*Ann. de Chim.* xxix. 207), one of the *savans* who accompanied Bonaparte in his expedition to Egypt. The following is the passage in the *Annales*, which purports to be an abstract of a memoir read at a meeting of the Institute, held at Cairo:—

"At sea it often happens that a ship seen from afar appears to be floating in the sky and not to be supported by the water. An analogous effect was witnessed by all the French during the march of the army across the desert. The villages seen in the distance appeared to be built upon an island in the midst of a lake. As the observer approached them, the boundary of the apparent water retreated, and on nearing the village it disappeared, to recommence for the next village. Citizen Monge attributes this effect to the diminution of density of the inferior layer of the atmosphere. This diminution in the desert is produced by the augmentation of temperature, which is the result of the heat communicated by the sun to the sands with which this layer is in immediate contact. . . . In this state of things the rays of light which come from the lower parts of the sky, having arrived at the surface which separates the less dense layer from those which are above, do not penetrate this layer; they are reflected, and thus form in the eye of the observer an image of the sky. He thus sees what looks like a portion of the sky beneath the horizon, and it is this which he takes for water."

The only objection which I think can be taken to this explanation of Monge, is that it seems to imply not a curvature, but an angle, in the course of the rays, just as in the case of what is called *total internal reflection* at the bounding surface of a piece of glass when the angle of incidence exceeds the critical angle.

Now, the formation of an angle (even a very obtuse angle) in a ray would require a perfectly sharp transition from one degree of density to another, instead of the gradual transitions which are more in accordance with our knowledge of the properties of air. We have shown that no such harsh supposition is necessary.

As to the propriety of applying the name *reflection* to

* A Paper read by Prof. J. D. Everett, M.A., D.C.L., before the Belfast Natural History and Philosophical Society. (Continued from p. 52.)

an action such as that represented in Figs. 4 and 5, it is perhaps just as proper as the application of the name *refraction* to the bending of rays which takes place in the atmosphere; the term *refraction* being primarily employed to denote bending not into a curve but into an angle, at places where a ray passes by a sharp transition from one medium into another.

The shaded region in Fig. 5 represents a portion of the atmosphere in which there is a rapid diminution of density upwards. We may regard it as the region of intermixture, between two portions of air, which differ greatly from each other in density, the denser portion extending downwards to the earth without any very rapid changes, and the rarer portion extending in a similar gradual manner upwards to the clouds. If these two dissimilar portions of air have been only recently brought into proximity, as by the commencement in the upper regions of a wind from some warm quarter, we should expect to find a border tract, where the transition would be unusually rapid, the border tract itself being indefinite in its

boundaries above and below, and the transition being most rapid in its central parts. The figure has been drawn to suit these suppositions, and it shows, besides two rays which have been reflected, a third ray which has barely been able to get through.

Anyone who is fresh from the study of optics will be at once struck with the analogy between the behaviour of these rays and of rays passing or endeavouring to pass from water into air; and the analogy is quantitative, as well as qualitative. For—

1. As regards those rays which get through, it can be shown that the total change of direction for a ray of a given incidence depends only on the densities above and below the region of intermixture, and is altogether independent of the thickness of this intermediate region. This is on the assumption that the surfaces of equal density are parallel planes. If, as in the case of air, the extreme relative index of refraction differs but little from unity, the change of direction is proportional to the tangent of the angle of incidence, and is equal to the

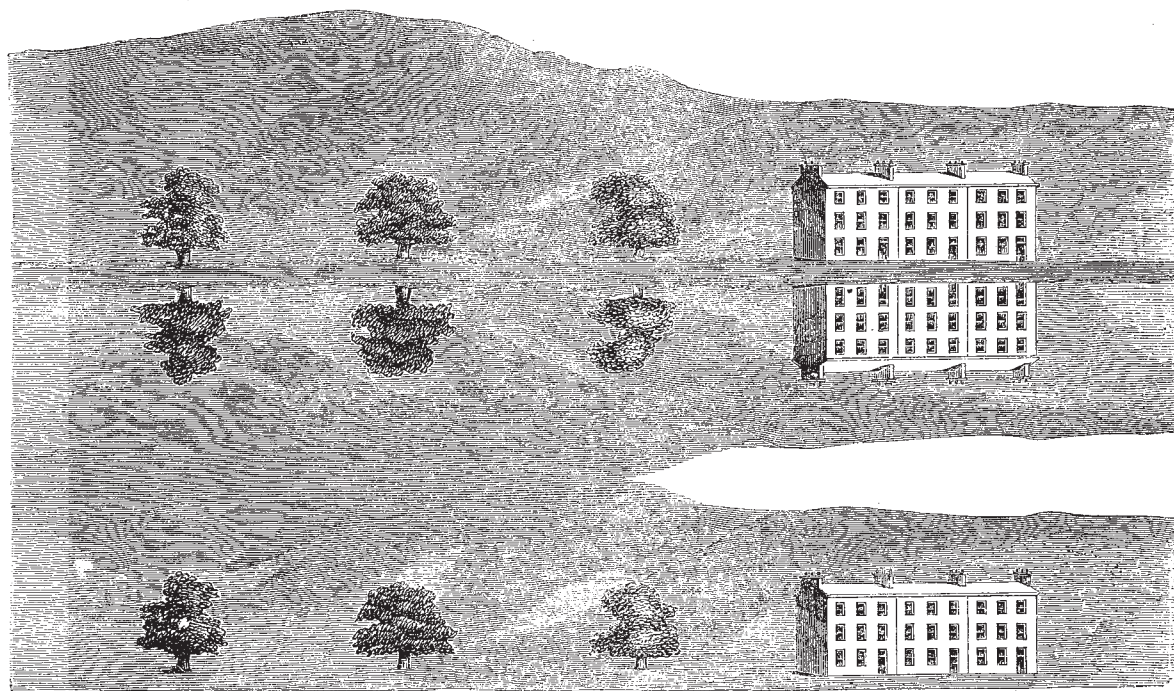


PLATE III.

product of this tangent by $\mu - 1$, μ denoting the relative index. This is the law which governs the refraction of rays from the heavenly bodies, in traversing the earth's atmosphere; except when these bodies are so near the horizon that the curvature of the earth and its atmosphere produces a sensible effect.

2. As a consequence of the preceding point of agreement, the critical angle which separates those rays which get through from those which are turned back, is also dependent solely on the comparison of the two extreme densities; that is, on the value of the relative index of refraction.

In the comparatively rare instances in which several inverted images of the same object have been seen in the sky, as in the third figure of Plate II., which represents a telescopic appearance observed by Scoresby, a possible explanation may be found in irregularities of form in the stratum of intermixture, which, instead of being truly horizontal, may be tilted to slightly unequal degrees in different parts, so that it acts, not like *one* plane mirror,

but like several plane mirrors slightly inclined to each other. Another, and I think more probable explanation, is the existence of more than one layer of rapid transition.

Whenever an image is inverted, the rays by which it is seen must have crossed; that is to say, the two rays which come to one and the same point of the eye from two neighbouring points of the object must have crossed each other once on the road. If they have crossed twice, the image will be erect; if three times, inverted; and so on.

When all the rays are circular arcs, and their curvatures are all equal, it will be impossible for them to cross, and hence no inverted image can be formed; neither can there in this case be any increase or diminution of apparent size. This is evident from the consideration that a diagram indicating the paths of such rays to the eye only needs to be bent with a curvature equal and opposite to that of the given rays, in order to render all these rays straight; and such bending will not affect the sizes of the images.

If, however, our rays are circular arcs of unequal curvatures, we may have crossing, and may also have magnification or diminution. It is obvious, from Figs. 6 and 7, that to give a magnified virtual image without crossing, the upper ray must be bent downwards more than the lower one; and that if the lower ray be bent down more than the upper, the image seen will be diminished.

These rules must be borne in mind in attempting to explain that very common form of mirage in which distant objects are greatly magnified in their vertical dimensions, without any other change. Fig. 4 may help us to understand how this magnification arises. If we suppose an object to travel along between two of the rays which proceed from the eye, it is clear from the diagram that the object will begin to be sensibly magnified as it enters the region of rapid change, and the magnification will increase as the object nears the intersection of these rays, at which point it becomes infinite, which practically means that, if placed at this point, it will give rise to an appearance of the greatest possible confusion. As it travels further away between the same two rays it will begin to be again recognised by a highly magnified and inverted image. One of the commonest, I believe the commonest, form of mirage in Australia is one in which small bushes at a distance are magnified into trees; and I believe the foregoing to be the correct explanation.

The magnification over water which gives rise to the architectural columns of the Straits of Messina and of the polar regions is more probably to be explained by the action represented in Fig. 6, the region of most rapid change of density being at a height somewhat greater than that of the top of the object, so that the top is greatly elevated by refraction, while the bottom remains nearly in its true place.

The quasi reflection illustrated in Fig. 4 may be produced artificially by carefully depositing alcohol or methylated spirit, to the depth of about an inch, upon water contained in a glass vessel with plane parallel sides. The spirit, though lighter, has a higher index of refraction than the water; and at the place of intermixture of the two liquids we have a gradual but very rapid diminution of index in descending. On bringing the eye close to the vessel, and looking obliquely downwards towards this part of the liquid, very perfect inverted images will be seen. The field of view afforded by this arrangement is, however, extremely limited; and a much finer effect is obtained by the arrangement now before you, in which three liquids are employed, the middle one having the highest index of refraction, while its specific gravity is intermediate between those of the other two. The three liquids are—(1) A strong solution of alum at the bottom; (2) pure water at the top; (3) Scotch whiskey mixed with enough sugar to make its specific gravity intermediate between those of the other two liquids. It is introduced last by means of a pipette.

Plate III. represents the appearance which this arrangement afforded when set up at a window of my house looking towards the mountains.

Every object in the landscape was tripled, the three images being seen at once; and the vertical breadth of the strip of landscape thus tripled at one view extended from the top of the hills down to the houses on the Lisburn road. The figure only shows the more conspicuous objects. When the sun was shining on the front of the row of houses represented, which was nearly half a mile distant, I was able to see distinctly the chimneys and windows, and even to see whether the blinds were up, down, or half-way down. It was easy to fancy that the inverted trees and houses were the reflections of the upper ones in water. But a much more striking effect, as of water, was at the place which is left white in the figure, at the junction of the middle and lower image. This had all the appearance of a calm bay or lake glistening in the sunshine. There are only two natural objects

to which this peculiar glistening belongs, with brightness far surpassing that of all the dry and solid parts of a landscape. One of these is water, and the other is the sky. A bit of sky has, in fact, been trapped between two portions of land; and it is a similar trapping of sky in the midst of dry land that produces the irresistible impression of a lake of water in the mind of the traveller in the desert. The middle image is probably formed by rays which have taken a path something like those in Figs. 1, 2, and 3. The highest and lowest image are formed by rays which have only been bent one way.

The arrangement of three liquids just described, which was suggested to me by Prof. Clerk-Maxwell, is extremely effective, but requires much delicacy in its preparation to ensure success.

Triple images of objects below the level of the vessel may be obtained by employing only the two first-mentioned liquids—alum water and pure water, or strong brine and pure water. A little gentle stirring is advantageous whichever arrangement be employed, a glass rod being inserted vertically, passed a few times slowly round the circumferential portion of the liquids, and then withdrawn.

With the two-liquid arrangement I have obtained three spectra, the middle one inverted, by employing as object a horizontal slit in the shutter of a dark room; and very brilliant colour effects were obtained by bringing the eye to the conjugate focus of the slit. A screen held at this conjugate focus, which was at first close behind the vessel of liquid, and slowly receded day by day, received an image of the slit very similar to that which would be formed by a cylindrical lens.

In order to see the three images (or spectra), it was necessary to hold the eye behind the conjugate focus. When it was held in front (that is nearer to the vessel), only two images were seen, sometimes only one, the middle or inverted image being always wanting.

A similar lengthening of focus day by day was observed with the three-liquid arrangement, which would doubtless yield similar colour effects.

ON THE GEOGRAPHICAL DISTRIBUTION OF THE FALLOW DEER IN PRESENT AND IN PAST TIME*

NATURAL History shares with History the doubtful honour of having not a few chapters which are, to use a well-known expression of Talleyrand, nothing more than "des fables convenues," or which, in fact, contain generally accepted fabrications. To this shadowy side of science Geology gives the largest contributions, but Zoology, especially as regards the habits, habitats, and geographical distribution of animals, is by no means poor in them. Of the Fallow Deer (*Cervus dama*) it is generally stated in all zoological text-books, "It is a native of the Mediterranean area, and was introduced thence into Germany, Scandinavia, and England, after the Crusades." And yet the Fallow Deer was, many thousand years ago, not only an inhabitant of Africa and Western Asia, but also as much at home in Southern Russia, and even in Central Europe and Denmark, as in Italy and Southern France.

My researches into the geographical distribution of the Fallow Deer in former epochs have been caused (like those upon the history of the Domestic Fowl†) by a discovery in the ancient history of the city of Olmütz. In the same formation as the skull of the fowl there spoken of was

* By L. H. Jeitteles. Translated from *Der Zoologische Garten* for August 1874. [I have thought it desirable that this article should be better known, as even in such recent works as Mr. Boyd Dawkins' "Cave Hunting," and the new edition of Bell's "British Quadrupeds," the ancient fable of the Fallow Deer being indigenous only in Southern Europe is repeated.—P. L. S.]

† See *Der Zoologische Garten*, bd. xiv. pp. 55 et seq.